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TECHNICAL REPORT RD-AS-88-9

USING RANDOM NUMBER GENERATORS ON THE SENSOR SIGNAL PROCESSING SYSTEM

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Research, Development, and Engineering Center

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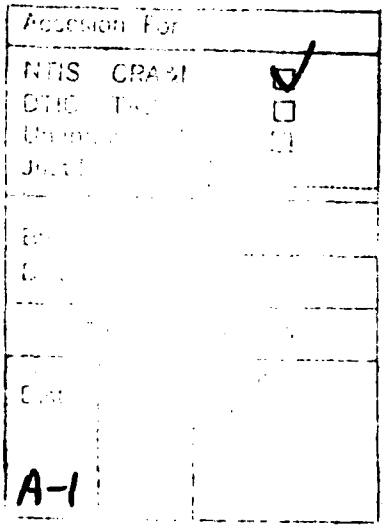
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I. INTRODUCTION

Random number generators are used in support of autonomous acquisition and processors for the sensor system processing system.

Three random number generators URAND (), ANRMRN (), and EXPRN () developed at Oak Ridge National Laboratory, are used for multiplicative noise added to images, computer benchmarking, and other scientific applications. URAND is a uniform number generator, ANRMRN is a normal number generator, and EXPRN is an exponential random number generator.

II. PROCEDURE

The random number generator requires an integer array (a block of memory) of dimension 4 (suggested name iseed) for the seed and a diskfile ranseed.dat in the working directory in order to execute. A seed is an initial value given to a random number generator and each individual seed produces a certain set of random numbers. Ranseed.dat is a diskfile that is opened by the program to hold the current seed and should initially contain a single record in 4o10 format (4 octal entries of length ten) of all zeros. RANFIX is the subroutine that initializes the program and must be called for the generators to work. RANFIX has to be called only once for each user program. If a certain seed is desired, the subroutine rango () is called to initialize the new seed, ex. call rango(iseed). If iseed(1), the first entry, in ranseed.dat is less than or equal to zero, then the seed is not initialized. If iseed(1) is greater than zero, the seed in ranseed.dat is used as the initial point for the random number generation. To save the current seed in the random number generator URAND, the subroutine ransav() is called, ex. call ransav(iseed). Ransav() copies the current seed into ranseed.dat and the array iseed. If the current seed is desired, call the subroutine ranfet(), ex. call ranfet(iseed). The Random Number Generator Parameters table contains the high value, low value, and the delta of these values for each random number generator (the default iseed is used). In the table, there are various amounts of random numbers generated ranging from 100-1,000,000 for each random number generator.

NOTE

> The normal and exponential generators use the uniform generator (URAND) to achieve their distributions. In other words, URAND is used to get random values for the generators ANRMRN() and EXPRN() to manipulate into their distribution.

The described functions and subroutines are in the library DISK$USERDISK:[SSPSLIB]RANDOM.OLB in the sensor signal processing system's VAX 11/785 of the Advanced Sensors Directorate. Provided, in this report, is an example of how the random number generators are used in a program and a figure showing a plot of the output of this program shown. The Appendix contains the random number program.

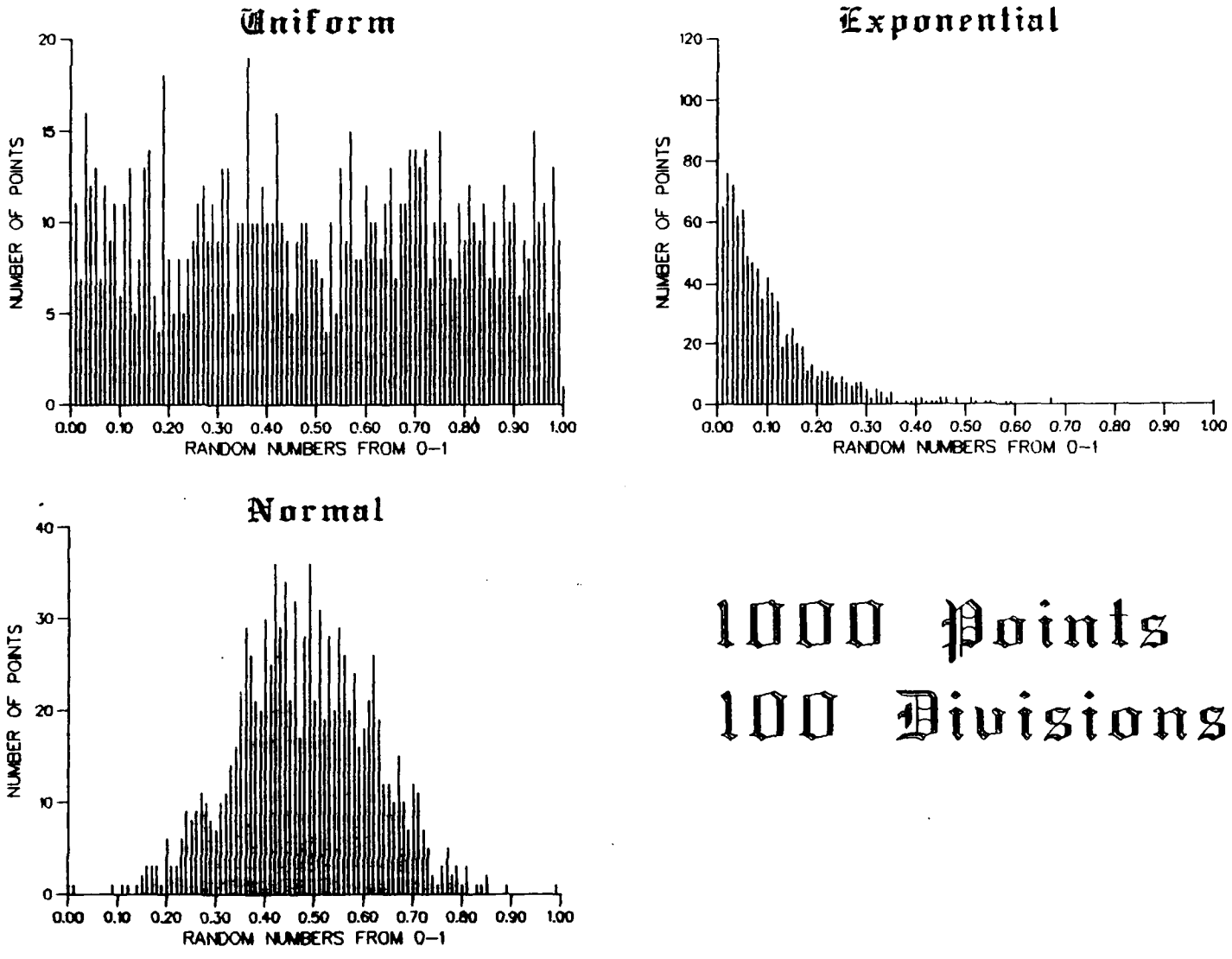


Figure. Plot of the program output.

TABLE 1. Random Number Generator Parameters

RANDOM NUMBER GENERATOR	POINTS	HIGH	LOW	DELTA
UNIFORM	1,000,000	0.99999 == 1	5.522E-7 == 0	APPROX. = 1
	500,000	0.99999 == 1	3.387E-6 == 0	APPROX. = 1
	100,000	0.99999 == 1	3.790E-6 == 0	APPROX. = 1
	10,000	0.99986 == 1	3.790E-6 == 0	APPROX. = 1
	1,000	0.99864 == 1	4.066E-4 == 0	APPROX. = 1
	100	0.99342 == 1	0.001432 == 0	APPROX. = 1
NORMAL	1,000,000	5.252260	-5.366426	10.61869
	500,000	4.526156	-4.321178	8.847335
	100,000	4.325014	-4.551002	8.876016
	10,000	3.684598	-3.702339	7.386937
	1,000	3.854763	-3.518877	7.373640
	100	3.023248	-2.448892	5.472140
EXPONENTIAL	1,000,000	14.76989	1.979E-6 == 0	APPROX. = 14.8
	500,000	13.37706	2.533E-7 == 0	APPROX. = 13.4
	100,000	12.88441	1.536E-5 == 0	APPROX. = 12.9
	10,000	10.94290	5.423E-5 == 0	APPROX. = 10.9
	1,000	10.19361	3.790E-6 == 0	APPROX. = 10.2
	100	3.612674	0.005789 == 0	APPROX. = 3.6

EXAMPLE :

Create the file RANSEED.DAT in your working directory

A SIMPLE PROGRAM

```
      INTEGER ISEED(4)
      REAL UNIFORM(1000),NORMAL(1000),EXP(1000),FRAN,DUMMY,DUMMY2

      DO I=1,4
      ISEED(I)=0
      END DO
      OPEN(UNIT=11,NAME='RANSEED.DAT',STATUS='OLD',FORM='FORMATTED')
      WRITE(11,10) (ISEED(I),I=1,4)
10    FORMAT(4o10)
      CLOSE(UNIT=11)

      CALL RANFIX

      DO I=1,1000

         UNIFORM(I)=URAND(FRAN)
         NORMAL(I) =ANRMRN(DUMMY)
         EXP(I)    =EXPRN(DUMMY2)

      END DO
      END
```

APPENDIX

RANDOM NUMBER PROGRAM

```
      SUBROUTINE RANFIX
C  SUBROUTINE TO INITIALIZE UNIFORM RANDOM NUMBER GENERATOR PACKAGE
C
C  SUBROUTINES RANSET,URAND,ANMRN AND EXPRN COMPRISE A PACKAGE OF RANDOM
C  NUMBER ROUTINES OBTAINED FROM THE OAK RIDGE NATIONAL LABORATORY (ORNL).
C  REFERENCE: E. J. MCGRATH AND D. C. IRVING, ORNL-RSIC-38 (VOL. II),
C  TECHNIQUES FOR EFFICIENT MONTE CARLO SIMULATION, VOLUME II,
C  RANDOM NUMBER GENERATION FOR SELECTED PROBABILITY DISTRIBUTIONS
C  URAND IS A MACHINE INDEPENDENT UNIFORM RANDOM NUMBER GENERATOR U(0,1).
C  ANMRN GENERATES NORMALLY DISTRIBUTED RANDOM NUMBERS N(0,1).
C  EXPRN GENERATES EXPONENTIALLY DISTRIBUTED RANDOM NUMBERS WITH UNITY MEAN.
C  RANSET IS AN INITIALIZATION ROUTINE FOR URAND.
C
C  RANFIX,RANGO,RANSAV AND RANFET ARE SPECIAL ROUTINES ADDED FOR IMPLEMENTATION
C  ON THE VAX.
C
C  TO MAKE POSSIBLE RESTARTING THE SEQUENCE WITH SPECIFIED SEEDS, ONE PROVIDES
C  IN THE CALLING AN INTEGER ARRAY (SUGGESTED NAME ISEED) OF DIMENSION 4.
C
C  IN ADDITION, A DISK FILE NAMED RANSEED.DAT IS REQUIRED FOR STORING THE
C  CURRENT VALUES OF ISEED.  THIS FILE SHOULD INITIALLY CONTAIN A SINGLE RECORD
C  IN 4O10 FORMAT WITH SUGGESTED ENTRIES ALL ZERO.
C
C  TO INITIALIZE THE PACKAGE CALL RANFIX.  THIS NEED BE DONE ONLY ONE TIME.
C  TO INITIALIZE TO A GIVEN RANDOM NUMBER SEED, ONE THEN CALLS RANGO(ISEED).
C  IF ISEED(1), STORED IN RANSEED.DAT, IS LESS THAN OR EQUAL TO ZERO, THEN NO
C  INITIALIZATION TAKES PLACE.  OTHERWISE, THE ISEED ARRAY STORED IN
C  RANSEED.DAT IS USED AS THE STARTING POINT FOR THE RANDOM NUMBER GENERATION.
C
C  TO SAVE THE CURRENT SEED IN URAND FOR FURTHER RANDOM GENERATION, CALL
C  RANSAV(ISEED).  THE CURRENT SEED IS OVERWRITTEN INTO RANSEED.DAT, IN
C  ADDITION TO THE CURRENT DATE AND TIME.  THIS SEED IS ALSO PLACED IN THE
C  THE ISEED ARRAY.
C
C  TO FETCH THE CURRENT SEED IN URAND (BUT NOT TO SAVE IT), CALL RANFET(ISEED).
C
C  IN ORDER TO BE ABLE TO REPEAT SIMULATION RUNS WITH THE SAME RANDOM NUMBER
C  SEQUENCE, IT IS SUGGESTED THAT THE INITIAL AND FINAL ISEED ARRAYS BE
C  PRINTED.
C
      DATA MAXINT/"17777777777/
      DATA NSTART/2001/
      CALL RANSET(MAXINT,NSTART)
      RETURN
      END
      SUBROUTINE RANSET(MAXINT,NSTRT)
C  SUBROUTINES RANSET,URAND,AMNMRN,EXPRN OBTAINED FROM OAK RIDGE
C  NATIONAL LABORATORY (ORNL)
      COMMON /MIRNG/RAN(10),GEN(10),NWRD,BASE,MOD,FBASE,FMOD
      INTEGER RAN,GEN,BASE,CARRY,REM
      MAXI=MAXINT/4
      IB=0
      BASE=1
   99 IF(BASE.GT.MAXI) GO TO 100
      BASE=BASE*4
      IB=IB+1
      GO TO 99
  100 BASE=2**IB
      FBASE=BASE
      NWRD=47/IB+1
```

```
      REM=47-18*(NWRD-1)
      MOD=2**REM
      FMOD=MOD
      DO 101 N=1,10
      RAN(N)=0
  101 GEN(N)=0
      GEN(1)=5
      DO 200 I=1,14
      CARRY=0
      DO 190 N=1,NWRD
      GEN(N)=GEN(N)*5+CARRY
      CARRY=0
      IF(GEN(N).LT.BASE) GO TO 190
      CARRY=GEN(N)/BASE
      GEN(N)=GEN(N)-BASE*CARRY
  190 CONTINUE
  200 CONTINUE
      NSTART=NSTRT
      IF(NSTART.LE.0) NSTART=2001
      NSTART=2*(NSTART/2)+1
      DO 300 N=1,NWRD
      NTEMP=NSTART/BASE
      RAN(N)=NSTART-NTEMP*BASE
  300 NSTART=NTEMP
      RETURN
      END
      REAL FUNCTION URAND(FRAN)
C  SUBROUTINES RANSET,URAND,AMNMRN,EXPRN OBTAINED FROM OAK RIDGE
C  NATIONAL LABORATORY (ORNL)
      COMMON /MIRNG/RAN(10),GEN(10),NWRD,BASE,MOD,FBASE,FMOD
      DIMENSION SUM(10)
      INTEGER RAN,GEN,BASE,CARRY,SUM,PROD,HPROD
      DO 30 IS=1,NWRD
   30 SUM(IS)=0
      DO 1 IG=1,NWRD
      N2=NWRD-IG+1
      DO 1 IR=1,N2
      IS=IR+IG-1
      PROD=RAN(IR)*GEN(IG)
      HPROD=PROD/BASE
      LPROD=PROD-HPROD*BASE
      SUM(IS)=SUM(IS)+LPROD
      IF(IS.LT.NWRD) SUM(IS+1)=SUM(IS+1)+HPROD
    1 CONTINUE
      N2=NWRD-1
      DO 5 IS=1,N2
      CARRY=SUM(IS)/BASE
      SUM(IS)=SUM(IS)-CARRY*BASE
      SUM(IS+1)=SUM(IS+1)+CARRY
    5 CONTINUE
      SUM(NWRD)=SUM(NWRD)-MOD*(SUM(NWRD)/MOD)
      DO 20 IS=1,NWRD
   20 RAN(IS)=SUM(IS)
      FRAN=SUM(1)
      DO 10 IS=2,NWRD
   10 FRAN=FRAN/FBASE+SUM(IS)
      FRAN=FRAN/FMOD
      URAND=FRAN
      RETURN
      END
```

```
      FUNCTION ANRMRN(DUMMY)
C  SUBROUTINES RANSET,URAND,AMNMRN,EXPRN OBTAINED FROM OAK RIDGE
C  NATIONAL LABORATORY (ORNL)
      R=URAND(D)
      IF(R.GT.0.8638) GO TO 10
      ANRMRN=2.*(URAND(D)+URAND(D)+URAND(D)-1.5)
      RETURN
   10 IF(R.GT.0.9745) GO TO 20
      ANRMRN=1.5*(URAND(D)+URAND(D)-1.0)
      RETURN
   20 IF(R.GT.0.997302039) GO TO 100
   25 X=6.*URAND(D)-3.0
      Y=0.358*URAND(D)
      XSQ=X*X
      GX=17.49731196*EXP(-XSQ*.5)
      AX=ABS(X)
      IF(AX.GT.1.0) GO TO 30
      IF(Y.GT.(GX-17.44392294+4.73570326*XSQ+2.15787544*AX)) GO TO 25
      ANRMRN=X
      RETURN
   30 AX3=2.36785163*(3.-AX)**2
      IF(AX.GT.1.5) GO TO 40
      IF(Y.GT.(GX-AX3-2.15787544*(1.5-AX))) GO TO 25
      ANRMRN=X
      RETURN
   40 IF(Y.GT.(GX-AX3)) GO TO 25
      ANRMRN=X
      RETURN
  100 X=SQRT(9.+2.*EXPRN(D))
      IF(URAND(D).GT.3./X) GO TO 100
      IF(URAND(D).GT.0.5) X=-X
      ANRMRN=X
      RETURN
      END
      FUNCTION EXPRN(DUMMY)
C  SUBROUTINES RANSET,URAND,AMNMRN,EXPRN OBTAINED FROM OAK RIDGE
C  NATIONAL LABORATORY (ORNL)
C  EXPONENTIAL RANDOM NUMBER BY VON NEUMANN REJECTION TECHNIQUE
      I=0
  100 R=URAND(D)
      X=R
  105 Y=URAND(D)
      IF(X.LT.Y) GO TO 120
  110 X=URAND(D)
      IF(X.LT.Y) GO TO 105
  115 I=I+1
      GO TO 100
  120 AI=I
      EXPRN=R+AI
      RETURN
      END
      SUBROUTINE RANSAV(ISEED)
C  SUBROUTINE TO SAVE RANDOM NUMBER SEED ON VAX
      COMMON /MIRNG/RAN(10),GEN(10),NWRD,BASE,MOD,FBASE,FMOD
      INTEGER RAN,GEN
      CHARACTER*9 IDATE
      CHARACTER*8 ITIME
      DIMENSION ISEED(1)
      DATA IRAN/11/
      DO 200 I=1,4
```

```
      ISEED(I)=RAN(I)
  200 CONTINUE
      OPEN(UNIT=IRAN,NAME='RANSEED.DAT',STATUS='OLD',FORM='FORMATTED')
      WRITE(IRAN,101) (ISEED(I),I=1,4)
  101 FORMAT(4O10)
      CALL TIME(ITIME)
      CALL DATE(IDATE)
      WRITE(IRAN,*) IDATE
      WRITE(IRAN,*) ITIME
      CLOSE(UNIT=IRAN)
      RETURN
      END
      SUBROUTINE RANGO(ISEED)
C  SUBROUTINE TO REINITIALIZE RANDOM NUMBER GENERATOR ON VAX
C  IF (ISEED(1).EQ.0) NO INITIALIZATION
C  IF(ISEED(1).LT.0) INITIALIZE WITH ABS(ISEED)
      COMMON /MIRNG/RAN(10),GEN(10),NWRD,BASE,MOD,FBASE,FMOD
      INTEGER RAN,GEN
      DIMENSION ISEED(1)
      DATA IRAN/11/
      ICLOSE=1
      IF(ISEED(1).GE.0) GO TO 180
      ICLOSE=0
      ISEED(1)=IABS(ISEED(1))
      GO TO 190
  180 CONTINUE
      OPEN(UNIT=IRAN,NAME='RANSEED.DAT',STATUS='OLD',FORM='FORMATTED')
      READ(IRAN,101) (ISEED(I),I=1,4)
  101 FORMAT(4O10)
      IF(ISEED(1).LE.0) GO TO 210
  190 CONTINUE
      DO 200 I=1,4
      RAN(I)=ISEED(I)
  200 CONTINUE
  210 CONTINUE
      IF (ICLOSE.LE.0) RETURN
      CLOSE(UNIT=IRAN)
      RETURN
      END
      SUBROUTINE RANFET(ISEED)
      COMMON /MIRNG/RAN(10),GEN(10),NWRD,BASE,MOD,FBASE,FMOD
      INTEGER RAN,GEN,BASE,CARRY,REM
      DIMENSION ISEED(1)
      DO 200 I=1,4
      ISEED(I)=RAN(I)
  200 CONTINUE
      RETURN
      END
      FUNCTION RAYLGH(R)
C  SUBROUTINE TO GENERATE SAMPLES FROM RAYLEIGH DISTRIBUTION WITH SIGMA=1
      DATA SQRT2/1.4142136/
      R=SQRT2*SQRT(-ALOG(URAND(DUM)))
      RAYLGH=R
      RETURN
      END
```

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